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MONTEREY, CALIFORNIA

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## MBA PROFESSIONAL REPORT

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### Filling H-60 Helicopter Readiness Shortfalls by Streamlining and Revising Depot Level Maintenance Procedures

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By:      **Timothy M. Snowden,**  
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             **December 2005**

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**FILLING H-60 HELICOPTER READINESS BY STREAMLING AND REVISING  
DEPOT LEVEL MAINTENANCE PROCEDURES**

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# **FILLING H-60 HELICOPTER READINESS BY STREAMLING AND REVISING DEPOT LEVEL MAINTENANCE PROCEDURES**

## **ABSTRACT**

Recognizing the need to extend aircraft service lives, Naval Air Systems Command developed the Integrated Maintenance Concept (IMC). IMC was seen as an opportunity to integrate tasks over all levels of maintenance and balance the operational, engineering, and fiscal aspects of an aircraft's preventative maintenance program.

Implementation of IMC has resulted in several unintended consequences, most importantly degraded readiness. Aircraft rebuild and in-process work required of squadron personnel interrupt maintenance at the squadrons and work stoppages interrupt flow at the depot. The result is wider variability in both processes, increasing inventory at the depot and squadron workloads, degrading operational availability by limiting aircraft inventory and interrupting production at the squadron.

The authors built a simulation model using Arena software to test the hypothesis that assigning organizational-level tasks to depot personnel would reduce variability in the process, and thereby decrease cycle times and depot work-in-process inventory. We concluded that implementing our project at a cost of \$1.4 million per year would be equivalent to having six additional aircraft, which implies savings of between \$36 million and \$150 million. Additionally, we concluded that the squadron labor freed from working on depot aircraft should result in increased operational readiness levels.

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## TABLE OF CONTENTS

I.	INTRODUCTION.....	1
A.	BACKGROUND .....	1
B.	AREA OF RESEARCH .....	2
C.	RESEARCH QUESTIONS .....	2
D.	METHODOLOGY .....	3
E.	STRUCTURE OF THE THESIS .....	3
II.	THE H-60 INTEGRATED MAINTENANCE PLAN .....	5
A.	BACKGROUND .....	5
B.	THE IMP PROCESS.....	5
1.	IMP Scope.....	5
2.	IMP Intervals .....	6
3.	Planned Maintenance Intervals Description .....	7
4.	Squadron Requirements.....	8
C.	CHAPTER CONCLUSION.....	11
IV.	OUR SIMULATION MODEL .....	13
A.	OVERVIEW OF MODELING AND SIMULATION.....	13
1.	What is Modeling and Simulation? .....	13
2.	Steps in Developing a Simulation Project.....	13
B.	ASSUMPTIONS.....	14
C.	SIMULATION COMMENCEMENT.....	16
D.	SIMULATION OF STATUS QUO.....	17
E.	SIMULATION OF PROPOSED ALTERNATIVE PROCESS.....	19
V.	SIMULATION RESULTS .....	21
A.	MODEL VALIDATION .....	21
1.	Cycle Times.....	21
2.	Work-in-Process Inventories .....	22
3.	Inductions and Throughput .....	22
B.	PROPOSED SYSTEM VERSUS STATUS QUO .....	22
1.	Cycle Times.....	22
2.	Work-in-Process Inventories .....	23
VI.	CONCLUSIONS, RECOMMENDATIONS, AND AREAS FOR FURTHER RESEARCH .....	25
A.	CONCLUSIONS AND RECOMMENDATIONS.....	25
B.	AREAS FOR FURTHER RESEARCH.....	26
1.	Verify Results by Examining the East Coast.....	26
2.	Examine the Financial Ramifications .....	26
3.	Apply to other Type/Model/Series Aircraft.....	26
	APPENDIX – CURRENT AND PROPOSED IMP PROCESS (ARENA SCREEN SHOT).....	27

<b>LIST OF REFERENCES.....</b>	<b>29</b>
<b>INITIAL DISTRIBUTION LIST .....</b>	<b>31</b>

## LIST OF FIGURES

Figure 1.	H-60 Planned Operational Interval (Coley, 2005).....	6
Figure 2.	IMP Zone Descriptions (Coley, 2005).....	7
Figure 4.	H-60 Ready for Squadron Acceptance (Kang, 2005) .....	9
Figure 5.	H-60 Ready for Squadron Acceptance (Kang, 2005) .....	9
Figure 6.	H-60 Ready for Squadron Acceptance (Kang, 2005) .....	10

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## LIST OF TABLES

Table 1.	IMP Induction Matrix (Coley, 2005).....	6
Table 2.	Zones Affected By PMI (Coley, 2005).....	8
Table 3.	NADEPNI Historical Data.....	17
Table 4.	Cycle Time Comparison .....	21
Table 5.	Work In Process Comparison .....	22
Table 6.	Proposal NMC Time .....	23
Table 7.	WIP Reduction.....	23

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## **LIST OF ACRONYMS**

BCA	Business Cost Analysis
CHSMWP	Commander, Helicopter Strike Wing, U.S. Pacific Fleet
FMC	Full Mission Capable
IMC	Integrated Maintenance Concept
IMP	Integrated Maintenance Plan
NADEP	Naval Air Depot
NADEPNI	Naval Air Depot North Island
NAVAIRSYSCOM	Naval Air Systems Command
NMC	Non-Mission Capable
NMCalt	Non-Mission Capable time alternative
NMCsqD	Non-Mission Capable time status quo Depot only
NMCsq	Non-Mission Capable time status quo
FIFO	First in First out
PMI	Planned Maintenance Interval
POI	Planned Operational Interval
RFT	Ready For Tasking
SDLM	Standard Depot Level Maintenance
STEP	Service Tour Extension Process
T/M/S	Type/Model/Series
WIP	Work In Process

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## **I. INTRODUCTION**

We will apply the integrated maintenance concept (a proactive, preventative maintenance process that improves reliability and availability of systems) to all tactical, non-commercially supported product lines, and will fully implement reliability centered maintenance to reduce maintenance demand.

Naval Air Systems Command Strategic Plan 2000-2005

### **A. BACKGROUND**

In the age of Defense Transformation, all agencies have been forced to look within themselves to find ways to sustain operations while maintaining high levels of material readiness. New funding is scarce and current aircraft must be maintained in order to last for many years into the future. In recognition of the need to extend the lives of numerous Type/Model/Series (T/M/S) aircraft, the Naval Air Systems Command (NAVAIRSYSCOM) developed the Integrated Maintenance Concept (IMC).

The Integrated Maintenance Concept was introduced in April 2000, calling for certain aircraft programs to transition to fixed operational service periods using Reliability Centered Maintenance analysis as a planning base for sustained maintenance. NAVAIRSYSCOM believed that by following the best commercial and industrial practices aircraft material conditions would improve, preserving numerous national assets. IMC was seen as an opportunity to integrate tasks over all levels of maintenance and to balance the operational, engineering, and fiscal aspects of an aircraft's preventative maintenance program. (Lockard, 2000)

The H-60 Helicopter has been in the Navy's arsenal since the 1980's. Numerous variants have been developed and fielded making it the primary logistics, search and rescue, and anti-submarine warfare helicopter in the Navy. The H-60 was one of the aircraft included in the integrated maintenance concept, beginning in 2002. Overall, the program has been beneficial for longevity of aircraft, but issues have been identified in the program's execution, primarily in aircraft preparation prior to Integrated Maintenance Plan (IMP) induction and aircraft rebuild following IMP maintenance.

Under the H-60 IMP, individual squadrons are required to prepare aircraft for induction into Naval Air Depots (NADEP). After the NADEP has completed IMP maintenance, the aircraft is returned to the squadron, requiring squadron personnel to rebuild the aircraft. It is within this period of rebuild that problems with the H-60 IMP have been seen.

Rebuild time of H-60's following the IMP process has been disturbing to leadership within helicopter wings, specifically the Commander, Helicopter Maritime Strike Wing, U.S. Pacific Fleet. In CHSMWP alone, rebuild times have averaged at 49 days, four days longer than the NADEP North Island requires to complete the Planned Maintenance Interval (PMI) process. At any given time, there is an average of nine aircraft undergoing this squadron rebuilding, causing the wing to miss readiness goals by approximately seven aircraft. (Venable, 2005)

Numerous questions are raised by these findings:

1. Why do squadrons perform the preparation and rebuild?
2. Why does the squadron take so long to rebuild an aircraft?
3. Can the depot perform these functions faster and what is the cost?
4. Will having the depot perform these functions increase readiness?

This project will answer these questions.

## **B. AREA OF RESEARCH**

Our project will examine the Navy's H-60 IMP. Our first goal is to show that NADEPs can perform all functions of the IMP faster than sharing responsibilities with individual squadrons. Our second goal is to show that operational readiness will be increased by the over all reduction of IMP cycle time.

## **C. RESEARCH QUESTIONS**

In order to achieve our goals, we will answer the following questions:

1. Why do squadrons perform the preparation and rebuild?
2. Why does the squadron take so long to rebuild an aircraft?

3. Can the depot perform these functions faster and what is the cost?
4. Will having the depot perform these functions increase readiness?

#### **D. METHODOLOGY**

This project will use simulation models to meet our objectives and demonstrate that NADEPs can complete all aspects of IMP, reducing overall cycle time and improving operational availability. We will first conduct a thorough review of the current H-60 IMP procedures. The baseline model will represent these current procedures.

The simulation models will be based upon information obtained from NADEP North Island and CHSMWP, both located in San Diego, CA. The focus will remain on these organizations because of proximity and clarity of data. Other H-60 wings and repair facilities will not be addressed in this thesis.

Utilizing this data, we will construct a baseline simulation. This simulation will be created in the Arena 7.0 simulation software package. The baseline simulation will be a representation of the current H-60 IMP. Our second simulation will represent an IMP in which the NADEP conducts preparation, IMP processing, and rebuild.

Upon completion of the simulations, we will analyze the results and determine the affects of an updated IMP on H-60 readiness.

#### **E. STRUCTURE OF THE THESIS**

The project will be structured into five chapters. Chapter I has provided a broad overview of the thesis subject, stated the objective of the thesis, identified research questions, described the scope of our research effort and presented our research methodology. Chapter II discusses the H-60 IMP in detail, showing procedures and methodology. Chapter III will present the ARENA simulation model of the current H-60 IMP for NADEP North Island and HSM Wing Pacific. Chapter IV will present a comparative analysis of our proposed H-60 IMP against the baseline simulation model of the current H-60 IMP. Chapter V presents a summary of our project research, conclusions, and recommendations for future study.

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## **II. THE H-60 INTEGRATED MAINTENANCE PLAN**

### **A. BACKGROUND**

The H-60 IMP was first implemented on August 1, 2002, in compliance with NAVAIRSYSCOM's IMC. One revision has been made since the IMP was developed. This thesis will outline the January 1, 2005, revision of the H-60 IMP. This overview will be very brief and the extreme details of the H-60 IMP can be found in the NAVAIR H-60B/F/H IMP Instruction.

### **B. THE IMP PROCESS**

#### **1. IMP Scope**

The H-60 IMP mandates four separate, Planned Maintenance Interval (PMI) airframe and component inspections, system operability checks, deficiency identification, correction, and preventive maintenance to provide aircraft serviceability through the next planned corrective maintenance interval. The requirements within the IMP are the minimum requirements necessary to ensure that aircraft undergoing the process are operationally available during the established, fixed service period. These processes are to be adequate to aircraft safety requirements and take into account reasonable economic considerations. (Coley, 2005)

Aircraft that have gone more than four years since its last Standard Depot Level Maintenance (SDLM) or Service Tour Extension Process (STEP) are required to undergo restorative maintenance in what the IMP describes as an IMP Baseline inspection prior to entering the IMP PMI cycle. This baseline is accomplished by undergoing PMI One through PMI Four concurrently. (Coley, 2005) The individual PMI levels will be detailed later. Aircraft with two years or less since its last SDLM are entered into the PMI cycle with PMI One. H-60's with greater than two years and less than four years since SDLM are inducted into the PMI cycle with PMI Two and Aircraft with two years or less since STEP will enter PMI One. (Coley, 2005) Figure 1 shows the induction matrix for the H-60 IMP.

AIRCRAFT ENTERING IMP					
YEARS SINCE SDLM	BASELINE	PMI 1	PMI 2	PMI 3	PMI 4
Less than 2		X			
2 to 4 *			X		
Greater than 4	X				
YEARS SINCE BASELINE					
Less than 2		X			
YEARS SINCE STEP					
Less than 2		X			
2 to 4 **			X		
FIRST TOUR NO SDLM/STEP	X				

Table 1. IMP Induction Matrix (Coley, 2005)

## 2. IMP Intervals

All H-60 T/M/S have been placed on a 96 month cycle with PMI Inspections occurring at the end of each Planned Operational Interval (POI) of 24 months. (Coley, 2005) This POI is currently being revised to a 36 month cycle, but that cycle length will not be examined by this thesis. To date, only three aircraft have undergone the new procedures, limiting the amount of data available. The data utilized in the ARENA model will be based upon the 24 month cycle. The following figure illustrates the POI for the H-60:

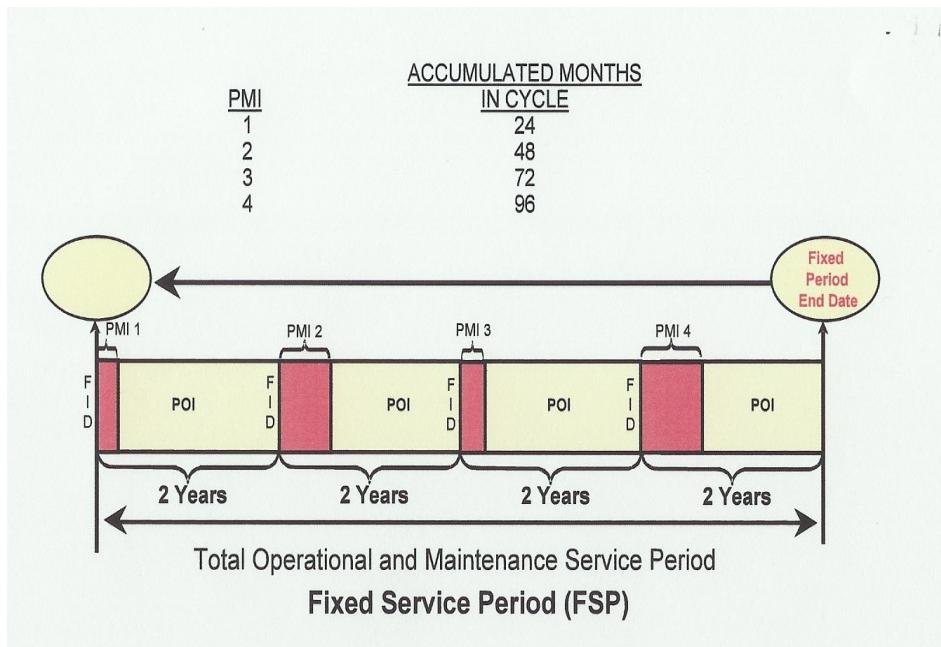


Figure 1. H-60 Planned Operational Interval (Coley, 2005)

### 3. Planned Maintenance Intervals Description

The intervals conducted by NADEPs are PMI's One, Two, Three, Four, and the Baseline. Under the new plan, there are two PMI's, PMI One N and Two N. Again, since only three aircraft have undergone the new process, there is not enough data to analyze, so this thesis will only focus on the old PMI processes.

For the purposes of PMI, the aircraft is separated into six zones. Figure 3 shows how the aircraft is divided.

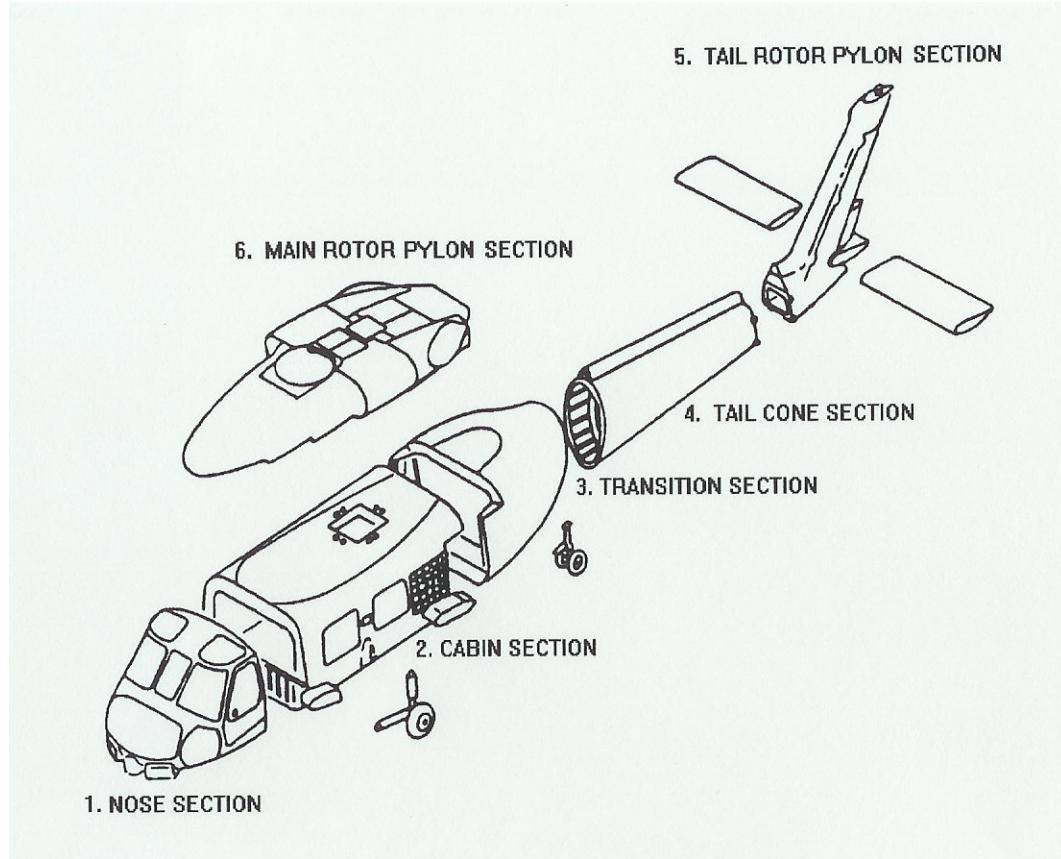


Figure 2. IMP Zone Descriptions (Coley, 2005)

Each zone is an area that is inspected during the PMI process and discrepancies corrected. The four levels of PMI inspect different zones, with the exception of the Baseline which examines all zones of the aircraft. (Brambila, 2005) Table 1 shows which zones are inspected by which PMI. The Baseline will be excluded from this table since all zones are affected by the Baseline.

<b>Zone Inspected</b>	<b>PMI</b>
One	Two and Four
Two	All PMI's
Three	Two and Four
Four	Four
Five	Two and Four
Six	Four

Table 2. Zones Affected By PMI (Coley, 2005)

During PMI, the aircraft undergoes extensive structural inspections. As illustrated in the zone breakdown, every system of the aircraft is inspected over a four year period. If discrepancies are discovered during the process of PMI inspections, the discrepancy is corrected by the depot team. (Brambila, 2005)

The PMI process takes approximately 45 days to complete. The 45 days is based upon the man hours that the depot charges NAVAIRSYSCOM. If an aircraft is taking less than 45 days to complete, personnel are moved to higher priority aircraft or other aircraft that are in an earlier phase of PMI. Switching the man power requirements causes all aircraft to be in the depot for approximately 45 days. (Brambila, 2005)

#### **4. Squadron Requirements**

During the development of the H-60 IMP, it was decided by NAVAIRSYSCOM that the individual squadrons would prepare the aircraft for induction into PMI. This preparation was above and beyond typical aircraft preparations, such as aircraft washes, special inspections, and equipment inventories. It was decided that major components, such as rotor blades, and sound proofing, would be removed. A full explanation of this preparation can be found in the NAVAIRSYSCOM Maintenance Requirement Card A1-H60CA-MRC-350. (Coley, 2005) The disassembly performed prior to IMP induction renders the aircraft Non-Mission Capable (NMC) or not able to fly. This disassembly time averages to about three days for CHSMWP. (Venable, 2005)

Upon completion of work by NADEP, squadrons receive the aircraft in a NMC status. Figures 4, 5, and 6 are examples of an aircraft that is ready for acceptance by the squadron.



Figure 4. H-60 Ready for Squadron Acceptance (Sullivan, 2005)



Figure 5. H-60 Ready for Squadron Acceptance (Sullivan, 2005)



Figure 6. H-60 Ready for Squadron Acceptance (Sullivan, 2005)

The pictures clearly show that the aircraft is not ready to fly. After acceptance, the aircraft becomes a very low priority for the squadron and is at high risk of cannibalization. Squadrons in HSM Wing Pacific have average rebuild times of 49 days per aircraft. Some take as few as three days where two squadrons took over 200 days to rebuild aircraft. The standard deviation of this data exceeds that of the mean, showing great variability within the rebuild process. On average, there are nine aircraft undergoing the rebuild process at any given time in HSM Wing Pacific which misses ready for tasking goals by seven aircraft. (Venable, 2005)

The decision to have squadrons rebuild aircraft was based upon the cost of depot labor. According to Mr. Victor Brambila, H-60 Project Manager at NADEP North Island, the depot can do the preparation and rebuild of the aircraft. Mr. Brambila stated that he would prefer to have the depot complete the preparation and rebuild because of work stoppages that are encountered if a step in preparation is missed and squadron personnel are required to come to the depot to do the work. Mr. Brambila's workers are

not authorized to do any work missed by the squadron because the depot is not funded to complete any preparation tasks. (Brambila, 2005)

NAVAIRSYSCOM completed an extensive Business Cost Analysis to determine if this was the best way to save money. The results of the BCA are deemed “Business Sensitive” by NAVAIRSYSCOM and can be obtained from Program Manager Air-299, but in order to keep this report unclassified and to have distribution unlimited, the results are not included. It will be stated that squadrons are rebuilding aircraft to save money in labor costs. (Cook, 2005)

### **C. CHAPTER CONCLUSION**

The H-60 Integrated Maintenance Plan is a good concept that has a major discrepancy; it creates variability by having two work forces, the squadron and the depot, with differing priorities working together. The differing priorities are natural, the depot wants to complete the IMP and the squadron is focused on flying aircraft. Though it saves money, this concept is hurting Navy readiness.

Cost has become the driving factor in many decisions made in designing the IMP. Analyzing this plan with a “bottom-line” mentality of dollars may help the Navy stay in budget, but this mentality is hurting the “bottom-line” of readiness. If the Navy invested money in having the depot complete 100% of the IMP for the H-60, or Full Mission Capable (FMC) in, FMC out, readiness will improve. Having all the cost savings in the world will not put more aircraft in the air, reducing the IMP cycle time will accomplish that goal.

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## IV. OUR SIMULATION MODEL

### A. OVERVIEW OF MODELING AND SIMULATION

#### 1. What is Modeling and Simulation?

Modeling and simulation is “a broad collection of methods and applications to mimic the behavior of real systems, usually on a computer with appropriate software...” as described by David Kelton, Randall Sadowski, and David Sturrock in the book *Simulation with Arena: Third Edition*. A real system, as defined by Kelton, is an actual or planned facility or process. (Kelton et al., 2004)

Les Oakshott of the University of the West of England, Bristol, describes modeling in his book *Business Modeling and Simulation*. “A model is a simplified representation of a system, where a system refers to any collection of objects or processes that interact in some way.” (Oakshott, 1997) Our model utilizes the Arena simulation software to represent the processes involved in the IMP of the H-60, showing how the squadron and the depot interact in order to return a helicopter to FMC status.

#### 2. Steps in Developing a Simulation Project

A successful simulation project requires certain steps, however there is no formal procedure to follow. Eleven general steps will be followed in order to develop the H-60 simulation model. These general steps will come from Les Oakshott, but items referring to the development of Arena specific issues will come from Kelton, Sadowski, and Sturrock.

- Formulate the Problem and Plan the Study
- Collect and Analyze the Data
- Build the Conceptual Model
- Check the Validity of the Conceptual Model
- Develop the Computer Model
- Verify (or Debug) the Computer Model
- Validate the Model
- Design Experiments
- Make Production Runs
- Analyze Output Data
- Write the Report and Make Recommendations

We will now describe the Arena model of the H-60 IMP in detail.

## B. ASSUMPTIONS

It would likely be impossible, and unnecessary, to model any complex process with absolute precision using software-based simulation tools. In fact, to attempt to do so would not only waste time but also defeat the purpose of simulation: to enable better-informed decisions with less investment in time. Therefore, in building models, assumptions are inevitable and indispensable.

The H-60 depot maintenance process is too complicated to model with absolute precision, so we have made several assumptions:

### **1. Inductions occur randomly.**

In reality, depot inductions are not random, but scheduled well ahead of time, so that both squadrons and the depot can make appropriate decisions regarding allocation of resources. However, because our simulation runs for ten years per replication, it would be impractical to build a schedule for that period of time. Therefore, we collected and analyzed data obtained from NADEP North Island (NADEPNI) which showed that, for the two-year period between July 2003 and July 2005, the depot inducted an average of 59 aircraft per year. Because there was no particular pattern discerned regarding the amount of time between inductions of helicopters at the depot, we have used a uniformly distributed random variable to simulate the time between arrivals.

### **2. The type of induction is randomly determined.**

As in the first assumption, in reality, not only the date of arrival is known well ahead of time, but also the type of induction, and again, we chose not to build a schedule for a ten-year period, but instead to utilize a discrete random variable to assign the type of PMI interval to each helicopter as it arrives.

### **3. Only teams of three artisans can be employed to work on helicopters.**

If a helicopter were to arrive at the depot and four idle artisans were available to work, the system would assign only three artisans to that aircraft. If, on the other hand, a

helicopter were to arrive into the system and only two artisans were available, the aircraft would wait in a queue until a third artisan was available for assignment.

Neither of the above situations is likely to occur in our simulation, however, since there are sixty ( $3 \times 20$ ) personnel available on day shift, and fifteen ( $3 \times 5$ ) on night shift. The significant drawback to this assumption is that we are unable to simulate assignment of artisans, either idle or working on lower priority aircraft, to aircraft of higher priority. In reality, if an aircraft is approaching its due date, it receives more attention than aircraft with later due dates, and may be assigned as many as six artisans working simultaneously. We have simulated the assignment of priority by closest due date, but this priority comes into play only once in the simulation, when the aircraft arrives in the queue and attempts to seize artisans for the first time.

Although this does not faithfully simulate the actual resource assignment process, Arena does not provide a straightforward method for duplicating the real process, so we have assumed that, on average, when a helicopter is being worked on, there are three artisans working simultaneously. This was necessary in order for the model of the *status quo* system to achieve the observed throughput of the actual system with comparable cycle times and in-process inventories.

#### **4. Teams assigned to an aircraft work continuously until completion.**

Production capacity in our model is similar to that in the real system: sixty personnel work an eight-hour day shift, fifteen work the eight-hour night shift. As in the actual system, there is no third-shift capacity and no capacity on weekends. Unlike the real system, however, we have not made provisions for overtime or holidays, whose effects would tend to cancel the other's out.

Because of a quirk in Arena, we have had to design the simulation to work each team continuously until its assigned aircraft has been completed; at that point, the team becomes unavailable while it takes all of time-off it has accumulated at once. This is known as the *Wait* option of the Arena Schedule Rule, and has the same overall effect on capacity and queue waiting time as teams taking time off as scheduled (see Kelton et al., pp. 123-124), except on the initial inductions. To counteract the initial effect on queue

wait times (the first twenty inductions would have close to zero wait times, for example), we have built a warm-up period of 1,000 days into the simulation, for which period no data are collected.

A note on our naming convention: we have named all four observed PMI events by number (PMI 1, PMI 2, PMI 3, and PMI 4). However, NADEPNI did not have any data on PMI 4 cycle times or labor hours, but they did have data on PMI Baseline events. These events are similar in length and process to PMI 4, but they are not identical; however, we felt that for ease of discussion, we would keep to a standard nomenclature. Throughout this paper, we will refer to all PMI Baseline data as PMI 4.

### C. SIMULATION COMMENCEMENT

The simulation begins with the creation of the first entity, an H-60 helicopter, at time zero. Subsequent entities are generated at random intervals based on analysis of historical data. The data show that, in a 104-week period, 119 helicopters were inducted into the IMC process at NADEPNI. This translates into 1.14 inductions per week, which equals an average of 6.1 days between inductions. To simulate that interval, we have used a uniformly distributed random variable with a minimum of 0.2 days and a maximum of 12 days.

The program then randomly assigns an induction type to the entity. The assignment is based on the historical data, from which we determined the actual proportion of total inductions for each type of induction. For example, historical data show that PMI 1 inductions represented approximately 35% of all H-60 PMI inductions into NADEPNI; therefore, in our model, there is a 35% chance that a newly-created entity will be assigned to the PMI 1 process. Likewise, the chances of the model assigning an entity to the PMI 2, PMI 3, and PMI 4 processes are 35%, 20%, and 10%, respectively.

Next, based on its assigned induction type, each entity is assigned a value representing the total number of man-hours which will be required to complete its depot maintenance process. In reality, when each helicopter arrives at the depot, this value has been largely predetermined based on its past operating conditions, but of course the exact

value can't be known. In the case of this simulation, we utilize four random variables (one for each PMI process) with triangular distributions to assign this value at the outset. The minimum values, modes, and maximum values of the distributions have again been determined by analysis of NADEP North Island historical data, and are displayed in Table 3.

	<b>Minimum</b>	<b>Mode</b>	<b>Maximum</b>
PMI 1	650	1200	2000
PMI 2	1600	3000	4400
PMI 3	800	1200	2000
PMI 4	4000	5800	7200

Table 3. NADEPNI Historical Data

At this point in the simulation, all of the attributes unique to each entity have been assigned: its time of arrival into the system, the type of depot process which it will undergo, and the amount of time that process will take to complete. The entity is then cloned, so that it can be simultaneously inducted into both the PMI process as it exists currently and our proposed system. In this way, the status quo can be directly compared to our proposed alternative process.

#### D. SIMULATION OF STATUS QUO

Now that the entity has been cloned, it enters our model of the PMI process as that process exists currently. The first step represents the organizational-level squadron's work to prepare the aircraft for induction. It is at this point in the actual process that the aircraft is first considered to be NMC, so it is at this point in the simulation that we increase the variable NMCsq by one ("sq" for status quo). We have only anecdotal data on which to base our model of this first step, but we found unanimity from polled squadrons that three days' time is sufficient to complete the preparation, so we have simulated this step with a delay of three days.

Upon completion of the aircraft preparation process, the squadron delivers the helicopter to the depot; the depot then promises to have the process completed on a specific future date. This promise date is based on corporate knowledge of the number of work-days a "typical" aircraft undergoing a specific process will require. We assign a

promise date within the model using the same estimates, and for much the same reason that the depot does: to determine which aircraft currently in-process have higher priority for assignment of personnel. NADEPNI assigns higher priority to an aircraft promised for return next week, for example, than to one which arrived earlier than that aforementioned aircraft but whose promise date is still several weeks away. Since NADEPNI does not use the “First-In-First-Out” (FIFO) rule to determine priority for assignment of personnel to work on an aircraft, neither do we use it in the model.

However, in our model, as at NADEPNI, we do use the FIFO rule for assignment of aircraft parking spots. Since there are finite numbers of parking spots at NADEPNI, we limit the resource (parking spots) within the model to 25, and as common sense would dictate, we assign each helicopter a parking spot as soon as it arrives, regardless of its promise date. It is at this point in the model that we also increase our second variable, NMCsqD (“D” for depot-only time), by one. This variable will be used to validate the model’s accuracy by tracking work-in-process (WIP) inventory at the depot for comparison to historical data.

Since depot artisans cannot work on two aircraft simultaneously, in our model, we limit the availability of artisans according to actual shift schedules. As discussed above in our description of assumptions, our model does not precisely mimic the actual process in assigning artisans, but the simulation will still provide accurate results for analysis. As each new aircraft enters the queue for the next available team of artisans, its place in line is determined by the promise date assigned earlier in the process. Those entities with the nearest due-dates are moved to the head of the queue. The effect is that aircraft accumulate all of their queue-waiting time at the outset, whereas in reality, a new queue forms at the beginning of each shift.

Upon successful seizure of a team of three artisans, the aircraft is delayed an amount of time equal to one-third of the total time to be spent within the process, as assigned upon creation of the entity. Since that time is assigned in man-hours, and there will always be exactly three artisans working on the aircraft, simulation process time—the “delay time”, in Arena syntax—is one-third of the assigned time. After the appropriate delay, the artisans working on the aircraft are released and take all of their

accumulated time off before becoming available for assignment to other entities that may be waiting in the queue. However, there is one hurdle still remaining before the aircraft can be returned to the squadron and its parking spot at the depot reassigned.

There are multiple aircraft discrepancies which may be discovered only after induction, once the depot inspection process has begun. In several of these cases, depot artisans must stop work once the discrepancy is discovered because, according to the IMC specification, the preparatory work *must* be done by organizational-level personnel. This requirement obviously induces delays in the processing of affected aircraft, though without tying up depot artisans. We have simulated this situation by delaying half of the aircraft an additional three days, again based only on anecdotal information, as provided by NADEPNI. The parking spot is then released for reassignment, the variable NMCsqD is reduced by one, and cycle time data are collected by process type for validation of the model's accuracy.

After the actual depot process has ended, however, the aircraft still has a long way to go before it is Ready For Tasking (RFT). Similar to the IMC specifications for organizational-level preparation for induction and organizational-level in-process preparation for correction of certain discrepancies, there is also a specification for organizational-level rebuild of aircraft following depot maintenance. Because this specification requires a significant investment of man-hours, and because squadron manpower is focused on maintenance required to meet the significant demands of the flight schedules for the current day or week, often aircraft returned from the depot do not reach RFT status for several weeks. We have simulated this fact with a further delay, based on historical data provided by CHSMWP. (We chose not to combine the data with other Wing commanders' data, since policies, procedures, and management styles have a significant effect on rebuild time and vary across Type Wings.) Finally, the variable NMCsq is reduced by one and additional cycle time data are collected.

## E. SIMULATION OF PROPOSED ALTERNATIVE PROCESS

Concurrent with the entity entering the status quo process, its clone enters a model of our proposed alternative process. As in the status quo process, the first step is again

squadron preparation of the aircraft; however, in our proposed process, we are recommending that at least some of the preparatory work be performed by depot artisans rather than organizational-level personnel. Therefore, we have simulated a delay of two days, saving one day of processing time as compared to the status quo, a conservative estimate in our opinion. Commencement of the process is captured, similar to above, by increasing the value of the variable NMCalt (non-mission capable, alternative process) by one.

Assignment of promise dates, priorities, helicopter parking spots, and artisans is done in processes separate from but identical to the processes in the status quo model. Because we are not modeling our proposed system on an existing system, we will not be validating this part of the model, and therefore we will not create a variable analogous to NMCSqD or collect the mid-process data that we collected in the status quo model.

The PMI process in our proposed process model is similar to the analogous process in the status quo model, with the exception being that 300 man-hours are added to each entity's required total processing time as assigned at creation. This figure represents the estimated additional labor required of the depot artisans in order to relieve the squadrons of some of the preparatory work and most of the rebuild work as currently defined in the IMC specification. As above, artisans are assigned in teams of three, and therefore the total process time in man-hours is divided by three to obtain total simulation time required for the PMI delay. Once the parking spot is released, the variable NMCalt is reduced by one and cycle time data collected by PMI type.

## V. SIMULATION RESULTS

### A. MODEL VALIDATION

In order to validate the accuracy of our model, we ran our simulation for a period of ten years, with warm-up periods of 1,000 days to bring the system to equilibrium before collecting data. This process was repeated for a total of thirty independent trials, and the results were averaged. We collected data on the aircraft at specific points during the simulation which correspond to endpoints in the real system for which historical data are available. Because we have based our status quo model on the existing system at NADEPNI, we would expect to obtain results which closely match the actual data collected from the real process at the depot. Conversely, if we have made inappropriate assumptions, we would expect to obtain results significantly different from those observed in the actual system.

#### 1. Cycle Times

We collected cycle time data at the point in the status quo model when the aircraft completed its depot-level process and was returned to the squadron. Because this cycle time interval began at creation of the entity, it includes the three days spent in preparation at the squadron; therefore, to compare our results to those obtained by NADEPNI, we must first subtract those three days or 72 hours from the cycle time. As can be seen in Table 4, considering the assumptions that we had to make, our results closely match those observed at NADEPNI.

PMI Event	Average Cycle Time (hrs)	Half Width 95% Confidence Interval	Subtract Squadron Prep Time (hrs)	Corrected Model Cycle Time (days)	Observed Cycle Times NADEPNI (days)
PMI 1	1,683	65	-72	67	57
PMI 2	2,456	81	-72	99	90
PMI 3	1,654	55	-72	66	66
PMI 4	3,597	183	-72	147	168

Table 4. Cycle Time Comparison

## 2. Work-in-Process Inventories

The variable NMCsqD kept track of the work-in-process (WIP) inventory during our simulation. Arena analyzed NMCsqD as a time-persistent variable, and the results closely matched those observed at NADEPNI from January 2003 through January 2005, as seen in Table 5.

	Model	Half Width 95% Confidence Interval	Observed Data NADEPNI
Average WIP	14	0.5	13
Avg Yearly Inductions	44	0.5	59
Avg Yearly Throughput	43	0.4	58

Table 5. Work In Process Comparison

## 3. Inductions and Throughput

Our model averaged only 435 aircraft inducted per ten-year replication, for an average of approximately 44 aircraft inducted per year. In comparison, NADEPNI inducted 119 aircraft in a two-year period, for an average of nearly sixty aircraft per year. The throughput rates compared similarly: our model averaged only 43 aircraft completed per year, while NADEPNI averaged 58 (see Table 5).

## B. PROPOSED SYSTEM VERSUS STATUS QUO

The only measurement that really matters in naval aviation is total number of aircraft ready-for-tasking (RFT). By defining the length of the IMC cycle as the total amount of time an aircraft remains NMC as a result, directly or indirectly, of the PMI process, we can directly measure the effect of that process on readiness. In this comparison, therefore, we include the time required to rebuild aircraft upon completion of the PMI process.

### 1. Cycle Times

In order to capture the entire interval during which aircraft are NMC, in the model of the process as it currently exists, we collected data for analysis at the point where the squadron finishes rebuilding the aircraft. Since our proposed process includes rebuilding the aircraft prior to their return to the squadron, it is at that point that we collect the data.

As can be seen from Table 6, in the case of each PMI process, our proposed model demonstrates a significant improvement in cycle times over the current process.

PMI Event	Status quo: Average Total NMC Time (days)	Half Width 95% Confidence Interval	Proposed: Average Total NMC Time (days)	Half Width 95% Confidence Interval	Reduction in Total NMC Time (days)
PMI 1	119	3	78	3	41
PMI 2	151	4	112	4	39
PMI 3	118	4	79	3	39
PMI 4	199	8	168	9	31

Table 6. Proposal NMC Time

## 2. Work-in-Process Inventories

Over the course of the simulation runs, the variables NMCsq and NMCal<sup>t</sup> kept track of the work-in-process inventories held in the model of the status quo system and our proposed system, respectively. These variables were analyzed over time, and the time-persistent averages were calculated by Arena. Table 7 displays the reduction in work-in-process inventory achieved by our proposed model in comparison to the model of the status quo.

Average WIP	Status Quo	Half Width 95% Confidence Interval	Proposed	Half Width 95% Confidence Interval	Reduction in WIP
	22.5	0.6	16.2	0.7	6.3

Table 7. WIP Reduction

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## **VI. CONCLUSIONS, RECOMMENDATIONS, AND AREAS FOR FURTHER RESEARCH**

This chapter will present our project conclusions, recommendations, and recommended areas for further research. The questions posed in Chapter I have been answered through the text, so the conclusions and recommendations below are displayed in a “bottom-line” fashion. Each conclusion will be immediately followed by recommended courses of action. The recommended areas of further research are presented as opportunities to validate this project.

### **A. CONCLUSIONS AND RECOMMENDATIONS**

1. The process modeled in Arena which represents the status quo is an accurate representation of the depot process at NADEP North Island. The results of the simulation runs, when compared to historical cycle-time and WIP data from NADEP, provide sufficient evidence to reach this conclusion.

We recommend that the Arena model developed for NADEPNI be applied to NADEP Jacksonville and the East Coast H-60 community. By applying the model to a separate, but similar entity it can be proven that our results are repeatable. We believe that this model can be applied to multiple aircraft communities

2. Changing the PMI process to assign tasks currently undertaken by organizational-level activities (aircraft preparation, certain in-process tasks, and aircraft rebuild) to depot personnel will reduce total cycle time for the PMI processes by four to six weeks. Because aircraft within the process are NMC, these reductions in cycle times will effectively increase the inventory of available aircraft by approximately six. We base this conclusion on the simulation results, as well as the fact that the cycle time reductions were accompanied by a proportional reduction in WIP, as predicted by Little’s Law. (Little, 1961)

We recommend assignment of all tasks associated with the PMI process to depot-level personnel. Doing so will reduce the wide variability that exists within the current process, thereby reducing cycle times and work-in-process inventories. By decreasing

WIP inventories at the depot, flight-line inventories increase; by freeing up sailor labor currently allocated to performing PMI process tasks, the operational readiness of those flight line inventories can be improved.

3. We estimate that, under the old PMI schedule, our proposal would cost less than \$1.4 million per year to implement, and would put, on average, six additional aircraft on the flight line every day. Discounted over a twenty-year period at a rate of 7%, the present value of the total cost of the project would be \$14.8 million. The result of implementing the project would be equivalent to having six additional aircraft, which, at a cost of \$6 million for an SH-60B and \$25 million for an SH-60R, would imply potential savings of between \$36 million and \$150 million. Based on our estimates, we recommend that NAVAIRSYSCOM adopt this proposal.

## **B. AREAS FOR FURTHER RESEARCH**

This project has shown numerous areas in which further research may be beneficial. Some suggestions include:

### **1. Verify Results by Examining the East Coast**

We recommend that the Arena model developed for NADEPNI be applied to NADEP Jacksonville and the East Coast H-60 community. By applying the model to a separate, but similar entity it can be proven that our results are repeatable. We believe that this model can be applied to multiple aircraft communities.

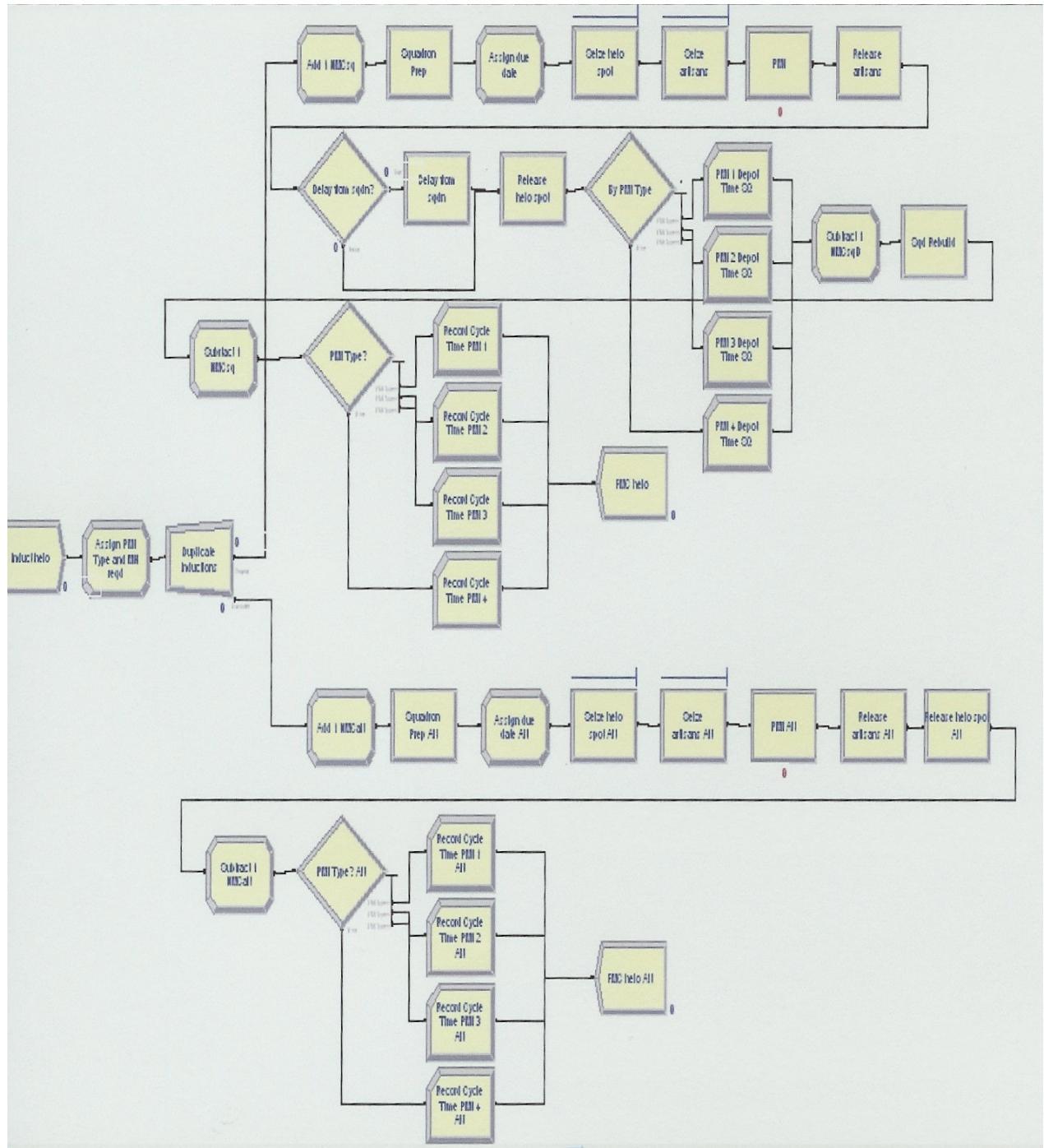
### **2. Examine the Financial Ramifications**

It is recommended that the financial ramifications of improving the efficiency of the Depot be analyzed. The improved efficiency may result in a decrease in the amount of man hours required to complete the IMP process, possibly affecting the amount of money required per man hour.

### **3. Apply to other Type/Model/Series Aircraft**

If the results of the ARENA model are repeatable for the East Coast, we highly recommend modeling the Depot Level maintenance procedures for all aircraft T/M/S currently in the Navy's arsenal. By modeling the processes, changes can be made to help increase overall operational availability for the Navy.

## APPENDIX – CURRENT AND PROPOSED IMP PROCESS (ARENA SCREEN SHOT)



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